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| --- | --- | --- | --- |
| *Title:* | **3D-CE6: Simplification of Simplified Depth Coding (SDC)** | | |
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# Abstract

This contribution presents a simplification of the Simplified Depth Coding (SDC) tool, which proposed to the 2nd JCT-3V meeting in JCT3V-B0036 [[1](#Jäg1213)]. The proposed simplifications affect both, encoder complexity and the number of required CABAC contexts for SDC symbols.  
For the reduction of encoder complexity the computed prediction signals are reused when testing SDC coding with and without residual DC offsets. By this modification the encoder runtimes can be reduced by approximately 18% compared to the HTM 5.0.1 anchor.

The second part of this contribution is about the reduction of required CABAC contexts for SDC. In JCT3V-B0036 there were some redundant context allocations and some more contexts were associated to the corresponding segment within SDC. This association is removed in this contribution.

For the CTC configuration [[1](#Hei11)] the proposed simplification yields a minor coding gain of 0.1%. This coding gain comes from the improved CABAC state initialization and a minor change to the SDC prediction modes. For the CE6 All-Intra coding configuration the proposed simplification results in a minor coding loss of 0.2% compared to the HTM 5.0.1 anchor.

# General Concept of Simplified Depth Coding

The SDC coding approach is an extension of the intra coding mode, which is available in the HEVC-based 3DV-HTM reference software. For an SDC-coded block, the prediction mode is still INTRA. An additional SDC-Flag signals the usage of the Simplified Depth Coding mode. If a block is coded with SDC, partition size is always inferred as 2Nx2N. Instead of coding quantized transform coefficients SDC-coded blocks need to code the following types of information:

1. The **type of segmentation/prediction** of the current block. Possible values are
   1. DC (1 segment)
   2. DMM Mode 1 – Explicit Wedgelets (2 segments)
   3. DMM Mode 2 – Intra-Predicted Wedgelets (2 segments)
   4. Planar (1 segment)
2. For the two DMM modes, additional prediction information is coded, as described in [[2](#Tec12)]
3. For each resulting segment, a **residual value** (in the pixel domain) is signaled in the bitstream

## Proposed Changes to SDC Coding

In this contribution two minor modifications to the SDC coding scheme as presented in JCT3V-B0036 are proposed. The first one only affects the encoder: By re-using the intra prediction signal when testing SDC coding with and without residual DC offsets for each segment, the encoder complexity can be reduced by about 20% as the number of times the encoder needs to compute the particular prediction signal is reduced significantly.

The second proposed modification affects the order of the available prediction modes for SDC coding. In JCT3V-B0036 the aforementioned order of prediction modes is used. As the Wedgelet prediction modes are less frequently used compared to the Planar prediction, in the proposed modification Planar prediction is shifted to the second position in the list. This results in a shorter coding word for Planar prediction as the used prediction mode in SDC is coded with unary length coding.

# Modifications to Required CABAC Contexts

The CABAC contexts that are used for SDC as described in JCT3V-B0036 are partially redundant, unused or independently defined for each segment of an SDC coded block. In this contribution it is proposed to remove this differentiation of contexts for each segment in a block. Moreover, the contexts for the sdc\_residual\_sign\_flag is removed completely. The number of contexts for sdc\_pred\_mode and sdc\_residual\_abs\_minus1 are also reduced.

# Modifications to Syntax and Semantics

## General Coding unit syntax

|  |  |
| --- | --- |
| … |  |
| if( sdc\_flag[ x0 ][ y0 ] ) { |  |
| **sdc\_pred\_mode** | ae(v) |
| if( sdc\_pred\_mode = = ~~1~~ 2 ) |  |
| **wedge\_full\_tab\_idx**[ x0 ][ y0 ] | ae(v) |
| if( sdc\_pred\_mode = = ~~2~~ 3) { |  |
| dmm\_delta\_end\_flag[ x0 ][ y0 ] | ae(v) |
| if( **dmm\_delta\_end\_flag**[ x0 ][ y0 ] ) { |  |
| **dmm\_delta\_end\_abs\_minus1**[ x0 ][ y0 ] | ae(v) |
| **dmm\_delta\_end\_sign**[ x0 ][ y0 ] | ae(v) |
| } |  |
| } |  |
| } else { |  |
| … |  |
| if( sdc\_flag ) { |  |
| sdcNumSegments = ( sdc\_pred\_mode = = ~~1~~ 2 | | sdc\_pred\_mode = = ~~2~~ 3 ) ? 2 : 1 ) |  |
| for ( i = 0; i < sdcNumSegments ; i++) { |  |
| **sdc\_residual\_flag**[ x0 ][ y0 ][ i | ae(v) |
| if( sdc\_residual\_flag [ x0 ][ y0 ][ i ]) { |  |
| **sdc\_residual\_sign\_flag**[ x0 ][ y0 ][ i ] | ae(v) |
| **sdc\_residual\_abs\_minus1**[ x0 ][ y0 ][ i ] | ae(v) |
| } |  |
| } |  |
| } |  |

**sdc\_pred\_mode** shall be one of the values shown in Table G‑3. sdc\_pred\_mode specifies the intra prediction mode used for simplified depth coding.

Table G‑3 – Interpretation of sdc\_pred\_mode

|  |  |
| --- | --- |
| **sdc\_pred\_mode** | Associated Intra Prediction Mode |
| 0 | Intra\_DC |
| ~~1~~2 | Intra\_DepthPartition( 35 ) |
| ~~2~~3 | Intra\_DepthPartition( 41 ) |
| ~~3~~1 | Intra\_Planar |

* + 1. Derivation process for luma intra prediction mode
* If sdc\_flag[ xB ][ yB ] is equal to 1, IntraPredMode[ xB ][ yB ] is derived as follows.
  + If sdc\_pred\_mode[ xB ][ yB ] is equal to 0, IntraPredMode[ xB ][ yB ] is set equal to 1.
  + Otherwise, if sdc\_pred\_mode[ xB ][ yB ] is equal to 1, IntraPredMode[ xB ][ yB ] is set equal to ~~35~~ 0.
  + Otherwise, if sdc\_pred\_mode[ xB ][ yB ] is equal to 2, IntraPredMode[ xB ][ yB ] is set equal to ~~41~~ 35.
  + Otherwise, if sdc\_pred\_mode [ xB ][ yB ] is equal to 3, IntraPredMode[ xB ][ yB ] is set equal to ~~0~~ 41.

Table G‑6 – Association of ctxIdx and syntax elements for each initializationType in the initialization process

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
|  | **Syntax element** | **ctxIdxTable** | **initType** | | |
| **0** | **1** | **2** |
| coding\_unit() | sdc\_flag | Table G‑15 | 0..2 | 3..5 | 6..8 |
| sdc\_residual\_flag | Table G‑16 | ~~0..1~~ 0 | ~~2..3~~ 1 | ~~4..5~~ 2 |
| ~~sdc\_residual\_sign\_flag~~ | ~~Table G‑17~~ | ~~0~~ | ~~1~~ | ~~2~~ |
| sdc\_residual\_abs\_minus1 | Table G‑18 | ~~0..19~~ 0..7 | ~~20..39~~ 8..15 | ~~40..59~~ 16..23 |
| sdc\_pred\_mode | Table G‑19 | ~~0..2~~ 0..1 | ~~3..5~~ 2..3 | ~~6..8~~ 4..5 |

* + - 1. Initialization process for context variables

1. Table G‑15 – Values of variable initValue for sdc\_flag ctxIdx

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Initialization variable** | **sdc\_flag** | | | | | | | | |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
| **initValue** | ~~0~~ 144 | ~~0~~ 154 | ~~64~~ 153 | ~~0~~ 141 | ~~0~~ 143 | ~~0~~ 143 | ~~64~~ 143 | ~~0~~ 143 | ~~0~~ 143 |

1. Table G‑16 – Values of variable initValue for sdc\_residual\_flag ctxIdx

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **Initialization variable** | **sdc\_residual\_flag** | | | | | |
| **0** | **1** | **2** | **~~3~~** | **~~4~~** | **~~5~~** |
| **initValue** | ~~251~~ 143 | ~~255~~ 143 | ~~0~~ 143 | ~~0~~ | ~~56~~ | ~~0~~ |

1. ~~Table G‑17 – Values of variable initValue for sdc\_residual\_sign\_flag ctxIdx~~

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| **~~Initialization variable~~** | **~~sdc\_residual\_sign\_flag~~** | | | | | |
| **~~0~~** | **~~1~~** | **~~2~~** | **~~3~~** | **~~4~~** | **~~5~~** |
| **~~initValue~~** | ~~255~~ | ~~255~~ | ~~0~~ | ~~252~~ | ~~55~~ | ~~0~~ |

1. Table G‑18 – Values of variable initValue for sdc\_residual\_abs\_minus1 ctxIdx

|  |  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **~~Initialization variable~~** | **~~sdc\_residual\_abs\_minus1~~** | | | | | | | | | |
| **~~0~~** | **~~1~~** | **~~2~~** | **~~3~~** | **~~4~~** | **~~5~~** | **~~6~~** | **~~7~~** | **~~8~~** | **~~9~~** |
| **~~initValue~~** | ~~255~~ | ~~255~~ | ~~64~~ | ~~0~~ | ~~2~~ | ~~0~~ | ~~64~~ | ~~0~~ | ~~6~~ | ~~0~~ |
|  | **~~10~~** | **~~11~~** | **~~12~~** | **~~13~~** | **~~14~~** | **~~15~~** | **~~16~~** | **~~17~~** | **~~18~~** | **~~19~~** |
| **~~initValue~~** | ~~67~~ | ~~0~~ | ~~8~~ | ~~0~~ | ~~61~~ | ~~0~~ | ~~7~~ | ~~0~~ | ~~47~~ | ~~0~~ |
|  | **~~20~~** | **~~21~~** | **~~22~~** | **~~23~~** | **~~24~~** | **~~25~~** | **~~26~~** | **~~27~~** | **~~28~~** | **~~29~~** |
| **~~initValue~~** | ~~243~~ | ~~255~~ | ~~12~~ | ~~0~~ | ~~14~~ | ~~0~~ | ~~33~~ | ~~0~~ | ~~243~~ | ~~255~~ |
|  | **~~30~~** | **~~31~~** | **~~32~~** | **~~33~~** | **~~34~~** | **~~35~~** | **~~36~~** | **~~37~~** | **~~38~~** | **~~39~~** |
| **~~initValue~~** | ~~2~~ | ~~0~~ | ~~66~~ | ~~0~~ | ~~0~~ | ~~0~~ | ~~63~~ | ~~0~~ | ~~1~~ | ~~0~~ |
|  | **~~40~~** | **~~41~~** | **~~42~~** | **~~43~~** | **~~44~~** | **~~45~~** | **~~46~~** | **~~47~~** | **~~48~~** | **~~49~~** |
| **~~initValue~~** | ~~12~~ | ~~0~~ | ~~50~~ | ~~0~~ | ~~14~~ | ~~0~~ | ~~27~~ | ~~0~~ | ~~0~~ | ~~0~~ |
|  | **~~50~~** | **~~51~~** | **~~52~~** | **~~53~~** | **~~54~~** | **~~55~~** | **~~56~~** | **~~57~~** | **~~58~~** | **~~59~~** |
| **~~initValue~~** | ~~239~~ | ~~255~~ | ~~14~~ | ~~9~~ | ~~27~~ | ~~0~~ | ~~0~~ | ~~0~~ | ~~239~~ | ~~255~~ |

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Initialization variable** | **sdc\_residual\_abs\_minus1** | | | | | | | | |
| **0** | **1** | **2** | **3** | **4** | **5** | **6** | **7** |
| **initValue** | 144 | 144 | 144 | 143 | 144 | 147 | 145 | 149 |
|  | **8** | **9** | **10** | **11** | **12** | **13** | **14** | **15** |
| **initValue** | 142 | 143 | 143 | 150 | 152 | 151 | 147 | 148 |
|  | **16** | **17** | **18** | **19** | **20** | **21** | **22** | **23** |
| **initValue** | 151 | 140 | 143 | 151 | 147 | 139 | 147 | 137 |

1. Table G‑19 – Values of variable initValue for sdc\_pred\_mode ctxIdx

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| **Initialization variable** | **sdc\_pred\_mode** | | | | | | | | |
| **0** | **1** | **2** | **3** | **4** | **5** | **~~6~~** | **~~7~~** | **~~8~~** |
| **initValue** | ~~9~~ 141 | ~~255~~ 156 | ~~70~~ 143 | ~~0~~ 143 | ~~9~~ 143 | ~~255~~ 143 | ~~70~~ | ~~0~~ | ~~9~~ |

Table G‑20 – Syntax elements and associated types of binarization, maxBinIdxCtx, ctxIdxTable, and ctxIdxOffset

| **Syntax element** | **initType** | **Type of binarization** | **maxBinIdxCtx** | **ctxIdxTable** | **ctxIdxOffset** |
| --- | --- | --- | --- | --- | --- |
| sdc\_flag | 0 | FL, cMax = 1 | 0 | Table G‑15 | 0 |
| 1 | 0 | Table G‑15 | 3 |
| 2 | 0 | Table G‑15 | 6 |
| sdc\_residual\_flag | 0 | FL, cMax = 1 | 0 | Table G‑16 | 0 |
| 1 | 0 | Table G‑16 | ~~2~~ 1 |
| 2 | 0 | Table G‑16 | ~~4~~ 2 |
| ~~sdc\_residual\_sign\_flag~~ | ~~0~~ | ~~FL, cMax = 1~~ | ~~0~~ | ~~Table G‑17~~ | ~~0~~ |
| ~~1~~ | ~~0~~ | ~~Table G‑17~~ | ~~2~~ |
| ~~2~~ | ~~0~~ | ~~Table G‑17~~ | ~~4~~ |
| sdc\_residual\_abs\_minus1 | 0 | FL, cMax = dltFlag ? Floor( Log2( num\_depth\_values\_in\_dlt ) : BitDepthY | 7 | Table G‑18 | 0 |
| 1 | 7 | Table G‑18 | ~~20~~ 8 |
| 2 | 7 | Table G‑18 | ~~40~~ 16 |
| sdc\_pred\_mode | 0 | U | 0 | Table G‑19 | 0 |
| 1 | 0 | Table G‑19 | ~~3~~ 2 |
| 2 | 0 | Table G‑19 | ~~6~~ 4 |

Table G‑21 – Assignment of ctxIdxInc to syntax elements with context coded bins

| **Syntax element** | **binIdx** | | | | | |
| --- | --- | --- | --- | --- | --- | --- |
| **0** | **1** | **2** | **3** | **4** | **>=5** |
| sdc\_flag | 0,1,2 ~~(subclause G.9.3.3.1.1)~~ | na | na | na | na | na |
| sdc\_residual\_flag | ~~0,1~~ 0 ~~(subclause G.9.3.3.1.7)~~ | na | na | na | na | na |
| ~~sdc\_residual\_sign\_flag~~ | ~~0,1 (subclause G.9.3.3.1.7)~~ | ~~na~~ | ~~na~~ | ~~na~~ | ~~na~~ | ~~na~~ |
| sdc\_residual\_abs\_minus1 | ~~0,10~~ 0 ~~(subclause G.9.3.3.1.7)~~ | | | | | |
| sdc\_pred\_mode | 0 | 1 | ~~2~~ na | na | na | na |

* + - * 1. ~~Derivation process of ctxIdxInc using segment index~~

~~Input to this process is the luma location ( xC, yC ) specifying the top-left luma sample of the current luma coding block relative to the top-left sample of the current picture.~~

~~Output of this process is ctxIdxInc.~~

~~If IntraPredMode[ xC ][ yC ] is not equal to 0 and IntraPredMode[ xC ][ yC ] is not equal to 1, ctxIdxInc depends on the SdcSegmentIndex = 0..1, as specified in Table G‑23.~~

~~Otherwise, the ctxIdxInc is equal to 0.~~

~~Table G‑23 – Specification of ctxIdxInc using segment index~~

|  |  |  |  |
| --- | --- | --- | --- |
| **~~Syntax element~~** | **~~IntraPredMode~~** | **~~SdcSegmentIndex~~** | **~~ctxIdxInc~~** |
| ~~sdc\_residual\_flag~~ | ~~IntraPredMode[ xC ][ yC ]  ==  0 || IntraPredMode[ xC ][ yC ]  ==  1~~ | ~~0~~ | ~~0~~ |
| ~~IntraPredMode[ xC ][ yC ]  !=  0 && IntraPredMode[ xC ][ yC ]  !=  1~~ | ~~0~~ | ~~0~~ |
| ~~1~~ | ~~1~~ |
| ~~sdc\_residual\_sign\_flag~~ | ~~IntraPredMode[ xC ][ yC ]  ==  0 || IntraPredMode[ xC ][ yC ]  ==  1~~ | ~~0~~ | ~~0~~ |
| ~~IntraPredMode[ xC ][ yC ]  !=  0 && IntraPredMode[ xC ][ yC ]  !=  1~~ | ~~0~~ | ~~0~~ |
| ~~1~~ | ~~1~~ |
| ~~sdc\_residual\_abs\_minus1~~ | ~~IntraPredMode[ xC ][ yC ]  ==  0 || IntraPredMode[ xC ][ yC ]  ==  1~~ | ~~0~~ | ~~0~~ |
| ~~IntraPredMode[ xC ][ yC ]  !=  0 && IntraPredMode[ xC ][ yC ]  !=  1~~ | ~~0~~ | ~~0~~ |
| ~~1~~ | ~~10~~ |

# Simulation Results

The simulations were performed according the common test conditions [[1](#Hei11)]. For the All-Intra coding scenario, configuration files from Core Experiment 6 on Depth Map Intra Coding Tools were used.

## Random Access Coding Configuration (CTC)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | video 0 | video 1 | video 2 | video only | synthesized only | coded & synthesized | enc time | dec time |
| Balloons | 0,0% | 0,0% | 0,0% | 0,0% | -0,1% | -0,1% | 95,3% | 101,1% |
| Kendo | 0,0% | 0,0% | 0,0% | 0,0% | -0,4% | -0,4% | 96,1% | 100,2% |
| Newspaper\_CC | 0,0% | 0,0% | 0,0% | 0,0% | -0,1% | -0,1% | 93,7% | 99,3% |
| GT\_Fly | 0,0% | 0,0% | 0,0% | 0,0% | -0,1% | -0,1% | 98,3% | 100,7% |
| Poznan\_Hall2 | 0,0% | 0,0% | 0,0% | 0,0% | -0,1% | -0,1% | 96,0% | 99,8% |
| Poznan\_Street | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 97,0% | 97,4% |
| Undo\_Dancer | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 0,0% | 94,6% | 102,1% |
| 1024x768 | 0,0% | 0,0% | 0,0% | 0,0% | -0,2% | -0,2% | 95,0% | 100,2% |
| 1920x1088 | 0,0% | 0,0% | 0,0% | 0,0% | -0,1% | 0,0% | 96,5% | 100,0% |
| **average** | **0,0%** | **0,0%** | **0,0%** | **0,0%** | **-0,1%** | **-0,1%** | **95,9%** | **100,1%** |

## All-Intra Coding Configuration (AI)

|  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- |
|  | video 0 | video 1 | video 2 | video only | synthesized only | coded & synthesized | enc time | dec time |
| Balloons | 0,0% | 0,0% | 0,0% | 0,0% | 0,2% | 0,1% | 83,2% | 100,7% |
| Kendo | 0,0% | 0,0% | 0,0% | 0,0% | 0,2% | 0,2% | 81,7% | 102,1% |
| Newspaper\_CC | 0,0% | 0,0% | 0,0% | 0,0% | 0,1% | 0,1% | 79,2% | 101,4% |
| GT\_Fly | 0,0% | 0,0% | 0,0% | 0,0% | 0,2% | 0,2% | 82,5% | 99,5% |
| Poznan\_Hall2 | 0,0% | 0,0% | 0,0% | 0,0% | 0,2% | 0,2% | 81,3% | 98,7% |
| Poznan\_Street | 0,0% | 0,0% | 0,0% | 0,0% | 0,1% | 0,1% | 82,4% | 100,4% |
| Undo\_Dancer | 0,0% | 0,0% | 0,0% | 0,0% | 0,1% | 0,1% | 83,0% | 101,6% |
| 1024x768 | 0,0% | 0,0% | 0,0% | 0,0% | 0,2% | 0,1% | 81,4% | 101,4% |
| 1920x1088 | 0,0% | 0,0% | 0,0% | 0,0% | 0,2% | 0,2% | 82,3% | 100,1% |
| **average** | **0,0%** | **0,0%** | **0,0%** | **0,0%** | **0,2%** | **0,2%** | **81,9%** | **100,6%** |

# Cross Check

The cross check of the proposed modifications to the SDC tool was done by Ghent University. They investigated the source code modifications and ran the simulations for verification of the presented results.

In their investigation they did not find any problems with the source code. Their simulation results perfectly match with those presented in this document.

# Conclusion

In this contribution some modifications and simplifications to the Simplified Depth Coding method are proposed. These modifications result in a significantly reduced encoder complexity for the All-Intra coding configuration. Moreover, the coding gain is only slightly reduced for the All-Intra coding configuration and for the configuration following the CTC [[3](#Jäg1213)], coding gain is even slightly increased. Furthermore, the draft text for the 3D-HEVC Test Model is reduced and simplified significantly by the proposed modifications.

These results show the benefits of the proposed modifications to the SDC scheme and therefore should be adopted to the 3D-HEVC Test Model [[2](#Tec12)].

# References

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|  |  |
| --- | --- |
| [1] | Fabian Jäger, "3D-CE6.h results on simplified depth coding with an optional depth lookup table," Joint Collaborative Team on 3D Video Coding Extension Development (JCT-3V) of ITU-T VCEG and ISO/IEC MPEG, Shanghai, China, Doc. JCT3V-B0036, 2012. |
| [2] | Heiko Schwarz and Dmytro Rusanovskyy, "Common Test Conditions of 3DV Core Experiments," Joint Collaborative Team on 3D Video Coding Extension Development (JCT-3V) of ITU-T VCEG and ISO/IEC MPEG, Shanghai, China, Doc. JCT3V-B0132, 2012. |
| [3] | Gerhard Tech, Krzysztof Wegner, Ying Chen, and Sehoon Yea, "3D-HEVC Test Model 2," Joint Collaborative Team on 3D Video Coding Extension Development (JCT-3V) of ITU-T VCEG and ISO/IEC MPEG, Shanghai, China, Doc. JCT3V-B0132, 2012. |

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# Patent rights declaration

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